DESIGNING DYNAMIC NETWORKED SCORES TO ENHANCE THE EXPERIENCE OF ENSEMBLE MUSIC MAKING

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ABSTRACT

This paper describes the impetus for, and design and evaluation of, a pilot project examining the potential for digital, dynamic networked scores to enhance the experience of ensemble music making. We present a new networked score presentation system, and describe how it has evolved through a participatory design approach with a primary school orchestra and through one-off sessions with several other ensembles. The design process has highlighted key issues concerning synchronisation between conductor, performers and notation, and autonomy and adaptation for performers. These key points are discussed and we show indicative feedback from users of the system along with future plans for the project.

1. INTRODUCTION

It is well recognised that ensemble performance participation raises self-confidence [1], and more recent work indicates that this is only true when the experience is enjoyable and rewarding [2]. We are motivated by the possibilities for dynamic networked digital scores to enhance both access to and the experience of ensemble music making so that the benefits can be more widely shared.

Development of non-standard notation systems has historically been motivated in part by a desire to realise broader social and political ideals of engagement that common practice notation, as a closed system, is unsuited for [3],[4]. We are similarly concerned with promoting inclusivity, but focus on the potential for *mixed and modified* notation systems to increase engagement and enjoyment of notated ensemble music making.

The project impetus came from regular long term observation of a voluntary primary school orchestra activity, in which children showed signs of apparent distress when they got lost while trying to perform arrangements of classical and popular music. Following from this, a significant proportion of the conductor's time was spent helping students to find and keep their place in the score. This raised the question of whether a digital system could be developed to synchronise and highlight the performers' score with the conductor's, mitigating the chances of getting lost.

Such a system could also lower the bar of entry to ensemble playing, opening out the benefits of ensemble performance of pre-composed music to players without musical training. Although motivated by and designed for a specific user group, such a system could have huge potential benefit in supporting ensemble music in the classroom, as well as in therapeutic settings and community and professional creative music making.

In order to design and evaluate the potential for such systems, we have adopted an iterative participatory design methodology [5], with a team consisting of a composer/ arranger, programmer/ researchers and psychologists. In this paper we describe work to date on a pilot project exploring the high level question: *Could digital, dynamic networked scores be transformative to the experience of musical ensemble playing?*

In the remainder of the introduction we give an outline of the established benefits of active participation in group music making. The specific needs of our case study group are then given, before a summary of the aims of the project. Related research and commercial systems of relevance are described in section 2. Our design methodology, software design and repertoire choices are described in section 3; our evaluation strategies are outlined in section 4 and finally formative results and future directions are discussed.

1.1 General benefits of ensemble playing

Participating in orchestral and ensemble performance of notated music has been found to confer multiple benefits including enhanced perceptual, cognitive, creative, social and physical development and well being across all ages. Active engagement with practical music making in young people has been shown to augment a range of widely transferable skills including improved performance in reading, mathematics [6] and verbal memory [7]; enhanced auditory and audiovisual processing of speech and music [8] and increases in general Intelligent Quotient [9] have also been reported.

Collaborative music making is also known to enhance key aspects of social skills in all ages such as co-operation, commitment and mutual support and to increase a positive sense of shared accomplishment. Enhanced self-esteem, self-confidence, and sense of belonging as well as providing an outlet of relaxation are similarly cited as positive benefits [2]. The success of the recent Opera North residency programme, *In Harmony* provides a vivid real-world illustration of the transformative power of ensemble mu-

sic making across academic, social and personal lives of young people [1] .

As a shared experience that can bolster cognitive, creative, personal and emotional capacity, enhance well being and transcend linguistic and cultural boundaries, ensemble music making has tremendous potential as an activity in educational, social as well as therapeutic settings. However, the use of standard notation can exclude those without existing musical literacy skills and seem inaccessible to those who cannot afford or access private music lessons. Further, research shows that the positive effects of engagement on personal and social development are only conferred when the overall experience is *enjoyable and rewarding* [2]. This can be a real issue for inexperienced readers when they first start playing in ensembles: lack of confidence technically and especially with reading musical notation means they struggle to keep their place - this can be off-putting and distressing, especially for beginners, who may conclude incorrectly that they lack ability.

1.2 Southover CE Primary School (case study)

As noted in section 1, the impetus for this project came from observation of exactly this lack of confidence detracting from otherwise positive musical experiences. Whilst the ultimate scope of application is broader (see section 6), the school orchestra provides a case study with which to develop and evaluate a pilot system addressing core pedagogic themes.

In this particular school, rehearsals take place every Thursday morning during term, before school starts, from 8.15 to 8.55am. Each week, simple arrangements of classical or popular music are rehearsed and performed. Although styles vary, difficulty is fairly consistent and arrangements have certain things in common, including: brevity (typically 16 to 24 bars); flexible instrumentation; simpler parts for novices; lead lines normally for the confident 'treble' players (e.g. flute, violin); a basic bass line (e.g. cello); a keyboard part for teacher or other skilled volunteer to 'fill in'.

Even in shorter arrangements, it is quite common for students to get lost and for the performance to break down. The experience for the students is positive enough for them to attend (current membership is just over 20) but observation suggested that they also experience stress when they get lost. This is deleterious to enjoyment and therefore the benefits of the experience. The music teacher and ensemble leader describes the challenges of rehearsing:

> *Running a primary school orchestra is a rewarding but challenging task. ... The challenge of juggling the able and those who need support is always difficult. As the orchestra becomes larger, keeping the children all in the right place on the score becomes harder particularly those whose skills in reading musical notation is weak.*
> – Gill Fenton. Music teacher and ensemble leader.

[1] www.operanorth.co.uk/education/in-harmony

1.3 Summary of aims

The key question we addressed in this pilot programme is: *(How) Could a networked dynamic scoring system be transformative to the experience of musical ensemble playing?*

Software development requirements and evaluation methodology were designed to address the following sub-questions:

1. Could a digital system that promotes/supports ensemble music performance help mixed ability musicians to keep their place and understand the shape of the music?
2. How might this technology impact the student players' experience and enjoyment of music making?

   Given the characteristics of repertoire outlined above, in particular:

   (a) could a system help make longer musical structures more accessible to a wider group?
   (b) could a system facilitate the performance of ensemble music featuring more polyphony?
   (c) could a system support the performance of ensemble music that is initially unfamiliar (i.e. sight reading)?

2. RELATED PROJECTS

2.1 Pedagogic - notation support

Online, digital and off-line materials already exist to support musical ensemble performance but have hitherto not harnessed the potential of networking. For example, *Figure Notes* [2] which provides a paper and label based system for developing notation skills through a progressive approach from graphic notation to full musical notation; *Charanga* [3] also provides an extensive music teaching resource including a combination of digital support and materials to cultivate musical appreciation and performance in schools. A growing number of desktop and mobile apps also support the digitised score management: *Forscore* [4] , for example enables creation, download, management and sharing of PDF scores. Similarly, a number of interactive applications are emerging to support music pedagogy more broadly: *Smartmusic* [5] , for example, generates interactive scores from Finale files, and deploys real-time machine listening to track performance skills.

2.2 Digital Music Stands

Various commercial digital music stands exist which include progressive features such as remote page turning functionality and enlarging font size (e.g. *musicpad*, [6] textitsame page music [7] , *MusicReader* [8]). Some networked solutions also exist: *eStand* [9] supports document sharing

[2] http://www.drakemusicscotland.org/figurenotes
[3] http://charanga.com/site/
[4] http://forscore.co/
[5] http://www.smartmusic.com/
[6] http://www.musicpad.co.uk
[7] http://www.samepagemusic.com
[8] http://www.musicreader.net/
[9] http://www.estand.com

across a collection of stands, for example, but at the time of writing centrally coordinated dynamic update of content is not supported. Products which automatically annotate digital scores, such as *weezic* [10] also exist, but without networking capabilities.

2.3 Score Following and Networked Music

Decades of research in computer music provides inspiration for solutions to some of the technical challenges of the project. Research in score-following and gestural control, networked music and bespoke platforms for generative music are of particular relevance. Pioneered in the 1980s [10] and still an active area in Music Information Retrieval (MIR) today, *score-following* involves the analysis of a live audio input in order to provide real-time tracking of location in a predefined score. Although we do not plan to include any audio analysis features in the current project, technical aspects of this research may prove useful in the case where a conductor is present in order to enable their gestures to control the tempo and so presentation of the dynamic scores. Relevant technical solutions can also be found in research in Networked Music, a rapidly expanding community [11] exploring implications and applications of networking technology on performance practice e.g [11], [12]. Similarly, dynamic creation of musical scores which has been explored in the context of generative music [13] provides inspiration.

2.4 Realtime Scores

As the laptop approached ubiquity as a performance instrument in the early 2000s, an increasing number of practitioners and researchers explored *realtime notation* - traditional or graphic notation "which is created or transformed during an actual musical performance" [11] p.1. See [11] for a good selection of approaches to real-time notation practice, exploring musical, technical and design perspectives.

3. DESIGN

We developed a set of iOS applications to create a unique combination of these existing systems: an open source, networked, active, score display system. Apple's iOS was chosen as the platform for development, as it is currently the predominant choice in UK schools, with tablet use predicted to continue rising over the coming years to levels that could facilitate use by musical ensembles in a significant number of institutions [14].

We adopted a participatory design (PD) approach to the development of the system; an ethos which foregrounds 'designing *with* rather than *for*' stakeholders (see e.g. [5]). PD grounds design in a democratic process where designers work in-situ with a community; by encouraging participation from stakeholders the design process is more likely to reflect their needs. PD is an emergent process, with an artefact taking shape through regular engagements with the stakeholder community in which the design is iteratively refined. To this end we had regular meetings and workshops with the key stakeholders for this project: hands-on workshops with young people representative of the players in the orchestra; advisory group meetings with other music educators and performers; interviews with the classroom music teacher of our case study, sessions with the school orchestra and a series of engagements with a variety of musical ensembles to evaluate broader uses of the system. Themes arising from these meetings are outlined below in section 5.

3.1 Mobile Applications

The software takes the form of two iOS applications: *NETEM Conductor* (NC) gives the conductor control over instances of the slave application *NETEM Performer* (NP). NC presents the conductor with the full ensemble score, and allows them to control the position in the score. NP shows a section of the score, synchronised to the current position of the conductor's software. To aid performers, the current bar is highlighted in the score. The application can display parts for all instruments in the score; the performer selects the one they would like to view. The software is open-sourced, available on GitHub [12] .

3.2 Score Rendering

The application imports data in the widely used MusicXML format [15]. This enables compatibility with the majority of notation software and online score archives. We have developed our own lightweight rendering engine, using the OpenFrameworks [16] creative coding toolkit. Standard notation is represented using Adobe's *Sonata* font.

3.3 Networking

Our system uses Bluetooth 4 networking to synchronise the performer apps to the conductor. The use of this protocol instead of standard WiFi removes reliance on institutional networking systems or additional routing equipment, and also requires no configuration, making it simple and straightforward to use. Synchronisation data is multicast to all local devices through the advertising data block. By sharing data in this way, there is no need to create a formal connection between devices, and the system can thereby exceed the connection limit of 12 devices on the iOS bluetooth stack. Further to this, messages can be transmitted at a high frequency, every 1-2ms, compared to the 20ms minimum for Bluetooth characteristic notifications in iOS.

3.4 Conductor Control

PD sessions emphasised dynamic synchronisation between conductor, performers and the score as one of the key factors in the usability of the system (further discussed in section 5). The systems offers two options: automatic sequencing at a selectable tempo, or tap tempo control. The former is designed for early stages of learning a new piece when the ensemble leader might need to be 'handsfree' in order to direct sectionals – the system can also provide a

[10] `http://weezic.com`
[11] `http://networkmusicfestival.org`
[12] `https://github.com/NETEMSussex`

click track to assist time keeping. Tap tempo mode mimics the traditional model of conductor control and allows the conductor to advance of score beat by beat. A new motion tracking system is under development which will enable the conductor to control the score gesturally.

3.5 Repertoire

In 2014 the BBC released a film, *Ten Pieces*, aimed at young people to promote the excitement of classical orchestral music through visually engaging performances of music ranging from Handel to Anna Meredith. The BBC also supported this by commissioning static (PDF) parts for mixed ability performance and made them freely available online. All but four of these ten pieces are on IMSLP (because they are out of copyright). Selections of these works as well as new compositions were prepared in MusicXML format editions for the networked music notation system.

4. EVALUATION STRATEGY

The pilot project focused on specific features of the case study orchestra, but we are also concerned with the broader potential impact of networked digital scores in ensemble music making with a view to wider-ranging, longer term research and development. To this end, in addition to considering the effect of the introduction of the system within the case study primary school we trialled the system with three other existing ensembles of different musical styles, and staged a public event to see how *mixed* notations systems can support performers with an even wider range of musical experience.

4.1 Sessions with the Southover CofE Primary School Orchestra

The system was tested and developed throughout five rehearsals with a voluntary primary school orchestra group, culminating in a final performance in the school assembly. See figure 1. We recorded video documentation for all of these sessions, along with interviews with the conductor, performers and the parents who assist the running of the orchestra. Between these sessions, the software was iteratively refined based on feedback from all stakeholders. Along with the collected notes of the research team, these materials were archived for qualitative analysis.

4.2 Student surveys

The impact of the networked scores on the primary school pupil's experience of the orchestra was evaluated through survey-style questionnaires with the students, and a focus group with the students and music teacher who leads the session (both parties, being considered as 'users' in this setting) and analysis of video documentation of the sessions [13]. The Likert-style survey was designed to capture students' thoughts and feelings around their sense of belonging and worth within the orchestra, musical understanding, engagement and enjoyment. Students completed the survey every week for 5 weeks after orchestra practice using their usual paper scores and a further 5 weeks whilst rehearsals were run using the networked system. Familiarity with musical repertoire was controlled for by working with one new and one familiar piece of similar standards during both phases.

4.3 Further Ensemble Sessions

The system was used to facilitate a session combining professional classical players [14] together with rock musician students at the British and Irish Institute of Modern Music (BIMM) [15] – shown in figure 2. The system was also used for a rehearsal combining the same professional classical musicians with students from East Sussex Academy of Music.

4.4 Public performance

A public performance took place as part of Brighton Science Festival 2016. Members of the public with no musical experience were invited to come and take part in the rehearsal and performance of a new work by composer Ed Hughes for Sussex CoMA [16] (pictured in figure 3). Sussex CoMA is a sinfonietta orchestra of adult players with diverse backgrounds; public participants were recruited via the science festival. Scores for orchestral players were presented in standard western music notation; non-notation reading public participants had colour coded scores where simple note events corresponded to coloured pitched chime bars and bells. Two sets of rehearsals and performances (with up to 10 public members in each) were followed by a round table discussion. The event enabled the real-world testing of the potential for dynamic, networked, mixed notation systems to support high quality amateur music making in mixed ability ensembles.

5. DEVELOPMENT AND EVALUATION

Statistical analyses of the questionnaires and qualitative analysis of materials collected during the PD sessions is under-way and will be published in forthcoming journal articles. In this section we report indicative feedback, arising throughout the development and testing sessions, under a number of themes; quotes from players and workshop leaders are used to illustrate the ways in which work to date addresses our core research questions.

1. Presentation of performer parts.

   Ease of adoption versus ease of adaptation. As with all digital design projects, consideration must be paid to the degree to which operational metaphors of the 'analogue' tools should be followed versus introduction of new modes of interaction which take advantage of the unique dynamic, programmable capacities of digital media. The former guarantees rapid

[13] Evaluation methods have been subject to ethical review and approved by University of Sussex Social Sciences and Arts C-REC (ER/EDH20/1 and ER/EDH20/2)

[14] The Orchestra of Sound and Light, `http://www.orchsoundlight.org/`

[15] `http://www.bimm.co.uk/`

[16] Contemporary Music for All: http://www.coma.org

Figure 1. Rehearsals at Southover CE Primary School Orchestra Group.

Figure 2. Workshop at BIMM Brighton

Figure 3. Brighton Science Festival Open Rehearsal: Members of COMA play from standard notation displayed on the iPads; members of the public (back row) play simple pitched parts coloured-coded with their instruments.

adoption of the functionally familiar tool; the latter may ultimately confer advantages, but relies on good design to enable users to adapt. Our intuitions as performers were supported by comments from all groups: it was noted that being able to preview the forthcoming bars was crucial. Some individuals expressed an interest in embracing the potential of digital technology and developing a scrolling score; others wished to preserve static pages.

Based on early feedback, the performer software allowed four modes of presentation, which can be set by the conductor: 1) displaying a static page which 'turns' a la paper score; 2) slowly scrolling the notation, giving the player a dynamic 'look ahead' of X bars, 3) a hybrid model in which a new 'page' of staves is displayed after the end of the *penultimate stave*, 4) a mixed view with current location magnified, and small scale 'overview' of the piece. Option 3 proved the most popular as it allowed players the necessary 'look ahead' conferred by a static page of music, whilst mitigating against the urgency of page turning.

Autonomy. The software used in the workshops allowed only the conductor to control the position of the scores for the performers. In early workshops, some of the younger players felt frustrated at the lack of autonomy in viewing the score. This had obvious disadvantages when performing new music too. The final version therefore includes a 'browse mode' which allows players to scroll through their parts during a break in the rehearsal (i.e. X seconds after the conductor stops conducting).

2. Conductor control.

   In the first workshop we conducted, the score was sequenced by the conductor app, at a tempo selected by the conductor. This led to serious synchronisation issues when the musicians played rubato, as the conductor was unable to correct the constant score playback speed accurately. This highlighted the fundamental importance of synchronisation between conductor, performers and the score. In workshop two, we trialled a simple tap tempo device, where the conductor tapped a large button the tablet, to progress the score by one beat. Even without any sophisticated tempo detection algorithms, this was successful in resolving the synchronisation issues but introduced another problem by forcing a change of the conductors' behaviour. This approach evolved with feedback from the conductor of the primary school orchestra into a system that would sequence the score autonomously, but allow the conductor to intervene to adjust tempo. Informal feedback and observations indicate this system provides a sufficient balance between managing synchronisation and allowing expressive tempo variation; for example, it allowed the tempo acceleration in Grieg's *Hall of the Mountain King*, and also allowed the school conductor to walk around and help children while the sys-

tem played automatically.

Ideally the system would synchronise tempo to the motion of the conductor by observing their natural style of conducting. To this end we are currently designing a wearable wireless tempo estimation system using the Invensense MPU9250 motion sensor for use in the final trial. The test system will afford two modes of control: metronome mode where tempo is rigidly controlled by a clock and click track and expressive conductor mode, where tempo is inferred from the conductor's baton, allowing expressive beat-by-beat tempo variation.

5.1 Indicative results

Observations from sessions with all ensembles suggest that the simple intervention of dynamically highlighting the current beat and bar resulted in an increase in confidence in players of all abilities which led to both increased enjoyment and greater engagement in the music. Several players and attendant parents of the school orchestra also commented how much better the orchestra *sounded* - presumably due to the greater relaxation and enjoyment.

- Beginner students in the Lewes primary school orchestra group commented that in not having to concentrate so hard on keeping their place in the score, there were able to focus more on other aspects of their performance, such as intonation, and listening to the others.

- Similar responses came from players at the BIMM workshop:

  "it really facilitated a [first time] play through and we were able to get creative, all in one session" ;

  "I'm not used to reading gigs at all, I never read, and I thought my biggest fear was that I was going to lose my place and I found this really helpful because it allowed me - especially in the improvising parts - I could really focus on what I was playing and thinking more about how I phrased it and dynamics and stuff without worrying where I was."

- Some less confident members of the school group suggest that the networked scores not only enhanced their experience by supporting them in keeping their place in the music, but scaffolded their longer term musical learning:

  " The iPads has stopped me getting lost in the music and I thought I was letting down the team and they are making me feel happier and Im not letting them down and now I know where Im going. When it stops I get lost but it doesnt usually happen. Its better than sheet music when I got very lost. Other people were down below and I was at the top. I will be more confident going back to sheets it will be better because the iPads are helping me use the music."

  The possibility than enhancing the *experience* of playing (by reducing the stress of getting lost) may have positive long term impact on musical engagement is interesting and warrants further consideration and investigation.

- Comments from a parent-helper at the school group suggest that the young players felt more secure in general, and that this had an perceptible impact on their music making:

  "Ive been watching these sessions and I think its amazing how they all stay together; in the silences of 'In the Hall of the Mountain King' these are all observed; its been a fascinating experience. You lose that sense of panic when you dont know where you are...its really helped them to stay together and stay focused on the music."

- For the school group, the system enabled the orchestra to sight-read through an arrangement of Holst's *Mars* from *The Planets*, the conductor commenting *"that would be unthinkable without the iPads"*.

- In the public Science Festival performances, novice and non-musicians young and old were supported in actively participating in a public orchestral performance in a way which would not have been possible without the system. The potential for such mixed and modified notation systems for supporting mixed experience performances is really encouraging.

6. SUMMARY AND FUTURE DIRECTIONS

We developed a dynamic, networked notation system for iPads linked by a Bluetooth network. The system was designed and evaluated over several months in a series of Participatory Design workshops with a primary school orchestra club, as well as workshops with players with a range of other ages, genres and abilities. Initial results, illustrated by comments from stakeholders, point to the benefits of dynamic networked scores in pedagogic settings. As outlined in sections 1.2 and 1.3 we are addressing some very specific questions about musical engagement and the subjective experience of rehearsing and performing in amateur ensembles and assessing the impact of the introduction of the system with qualitative and quantitative methods. Initial results suggest that the system serves the primary function of supporting players in keeping their place. Individual feedback suggests that this has positive effect not only on immediate experience; the possibilities that this may aide longer term musical engagement, as well as impacting the quality of music making is implied and inspires further research. The Science Festival event in which members of the public played simple pitched parts within a contemporary music ensemble provided further insight into the possibilities for dynamic networked scores using a mix of standard and graphical notation to cohere mixed ability musicians in a single ensemble performance.

In future work we plan to explore how generalisable these observations are by investigating the creative musical, pedagogic and therapeutic possibilities of such technology using further modified (layered, augmented, annotate-able etc.) notation, experimental graphical notation and mixed

models (for example in electro-acoustic settings). In consultation with our advisory group, we see scope for adapting and extending this work to professional and wider adult community settings, where ideas about synced parts with richer elements of dynamic information may be productively explored (e.g. in experimental music, or professional classical ensembles), alongside the potential therapeutic benefits of ensemble performance experience amongst adult beginner musicians in different contexts, for example workshops for those recovering from the trauma of Accident and Emergency, arts therapeutic settings and so forth. In order to maximise accessibility we are currently planning ports to Android and ChromeOS to enable access beyond iPads.

The NETEM project brings together many elements of concern in contemporary music making, drawing from established research in experimental notation, networked music, dynamic scores and more recent commercial interest in music apps to develop a networked, dynamic music score presentation system. In a short term pilot we developed the system and are evaluating whether such technology can have a positive impact on the experience of ensemble music making. In future work we plan to explore dynamic networked scores of mixed and modified notation systems in a range of therapeutic, pedagogic and creative music settings.

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